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The Holocene History of Scots Pine (*Pinus sylvestris* L.) at Loch Sloy, Scottish Highlands

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ABSTRACT

Ancient Scots Pine stumps are commonly revealed by erosion of Scottish peat bogs especially in the Highlands. Stumps of Scots Pine which grew about 4750 years ago (calibrated C14 date) were recently discovered on the upper shores of Loch Sloy. With data from pollen and macroscopic fossil analyses, peat stratigraphy and radiocarbon dating, a relationship between the former growth of Scots Pine at Loch Sloy and intermittent fires is postulated; this is consistent with the ideas of palaeoecologists who have considered that fires may have been necessary to have allowed Scots Pine to grow on water-logged or otherwise unfavourable peat. On the basis of the 5% pollen threshold, it is deduced that Scots Pine grew around Loch Sloy between about 5000 and 3000 years ago.

INTRODUCTION

In 1997 a 2.5m long core of peat was recovered from the shore of Loch Sloy, an artificial reservoir, where Mr John Mitchell had previously noticed stumps of Scots Pine. As part of an ongoing investigation into the Holocene (post-glacial) history of Scots Pine in Scotland, the site was investigated using pollen and macrofossil analyses and radiocarbon dating of one of the stumps. The precise aims of the project were to determine:

1. When Scots Pine first colonised the area,
2. The exact period of growth of the trees that remain as stumps,
3. When Scots Pine became extinct in the area,
4. To compare the history of the Scots Pine at Loch Sloy with that of the trees in Glen Falloch, 12 km to the north-east, where the southernmost, extant, native British population grows.

The occurrences of Scots Pine in Scottish peat bogs have caused much comment over a long period, certainly back to the 18th century. The paper by Hilary Birks (1975) was a major, modern contribution to the understanding of the chronology and ecological settings of the preserved stumps, especially with regard to the importance of fire in allowing establishment of the trees on peat bogs. Since Hilary Birks' work, the increasing application of pollen analysis and radiocarbon dating to the elucidation of woodland history has made it abundantly clear that Scots Pine has had a very complex history in Britain, and Scotland in particular, since the last Ice Age, that is the last 11250 years (Bennett 1984, Hilary Birks 1972, 1975, John Birks 1989, Bridges *et al.* 1990, Dubois and Ferguson 1985, Gear and Huntley 1991).

The most recent attempt at a review of knowledge of the history of Scots Pine in Scotland is that by Bennett (1995). Among his six principal conclusions are two that are particularly relevant to this investigation.

Firstly, he states (p.35) "the spread of Pine was favoured by human activity after 5700 years ago, and it was the only tree to increase its range as the overall extent of woodland in northern and western Scotland contracted". Secondly, "in northern and western Scotland Pine was one of the forest dominants through the mid Holocene, but decreased in abundance at about 4400 years ago. This pine decline was irregular and patchy over the period 5200-3200 years ago, and possibly a consequence of climatic variation, especially involving precipitation".

Scots Pine readily colonises a variety of soils; highly podsolised, sharp draining sand and gravel are preferred, but also bog surfaces, depending on the type of peat and surface wetness. Scots Pine seedling establishment requires a symbiotic mycorrhiza. Colloidal *Trichophorum caespitosum* (Deer Grass) and *Molinia caerulea* (Purple Moor Grass) peat are deficient in phosphorus, essential for mycorrhizal growth, while *Calluna* (heather) peat is though to contain an allelopath which kills the mycorrhiza; both are therefore unsuitable for the establishment of Pine. Mesotrophic *Phragmites australis* (Common Reed) peat, however, contains the mycorrhiza and is conducive to the establishment of Pine seedlings (Birks, 1975).

According to Bennett's 1995 distribution map (Fig. 1), based on macrofossils, which are unequivocal evidence of former presence, Scots Pine has grown throughout most of Scotland, at some places more or less abundantly, at some time during the Holocene. The problem concerns the interpretation of pollen values as an index of presence. *Pinus* produces very large quantities of pollen which can travel over great distrances. Pollen analysts have mostly cautiously adopted a value of 20% of total pollen as necessary to prove local growth but now Bennett, following Fossitt (1994), has argued that only 5% suffices. On that basis, Scots Pine had spread across much of Scotland by 8,800 years ago but in low abundance.

SITE DESCRIPTION

The studied site is situated on the west shore of Loch Sloy (National Grid reference NN275137) at latitude 56°16' N, longitude 4°48' W, at an altitude of 290m above sea level and with

a south-easterly aspect. This is near the intersection of Loch Sloy, Strath Dubh-uisage and Allt a Chnoic (Figure 2). The area is surrounded by high hills, Cnap na Criche (515m) to the north, Beinn Dubh (773m) to the south, Conc (492m) to the west and Ben Vorlich (941m) to the east. Most of the site overlies Beinn Bheula schist, a metamorphosed Dalriadan sediment. The area over which soil has developed is now covered by ombrotrophic blanket bog. To the north and west of the site the alien conifer *Picea abies* (Norway Spruce) has been extensively planted. The stumps have been eroded from the lochside peat when the water level has been high (figure 3).

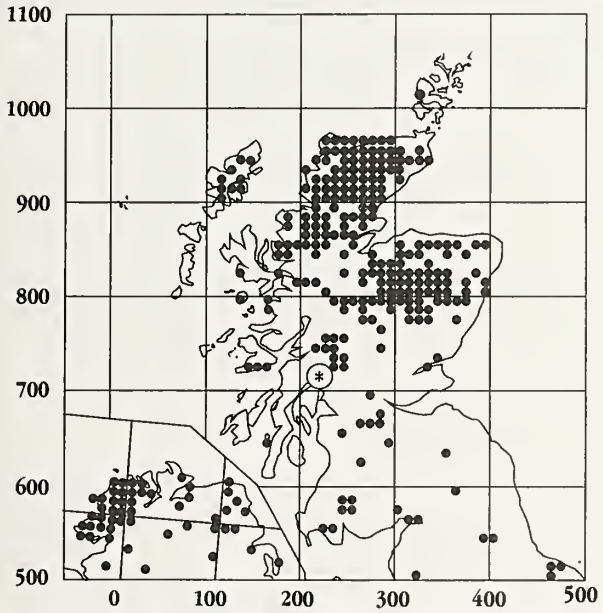

Figure 1. Stumps and other large remains of Scots Pine from peatlands in Scotland and adjacent regions, modified from Bennett (1994). The remains vary greatly in age some going as far back as 7000 years ago. The asterisked circle shows the location of the Loch Sloy stumps.

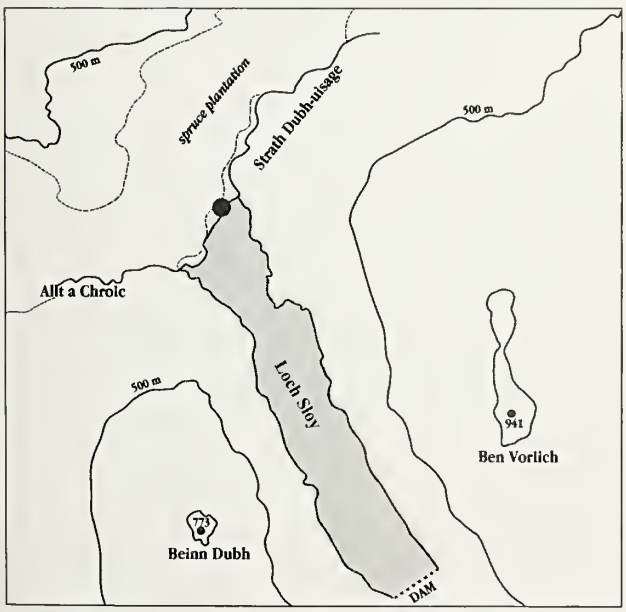

Figure 2. The Loch Sloy area. The location of the stumps is indicated by the black disc. Contours and spot heights are shown in metres above sea-level.

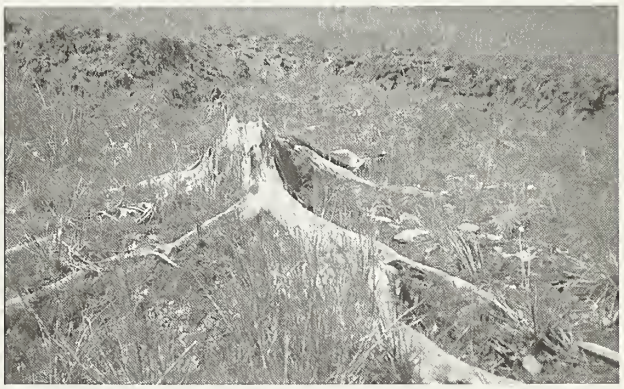

Figure 3. The Scots Pine stump which grew within a few meters of the dug out peat face used for pollen analysis, just out of picture top left. A piece of root wood from this stump was used for carbon dating and annual growth ring analysis.

Due to its proximity to the lochside the vegetation surrounding the stumps is a transition type including elements of National Vegetation Classification type M6, acid small sedge fen, and M24c, acid *Molinia* grassland.

SAMPLING OF PEAT, POLLEN AND MACROFOSSILS

At the face of an exposed peat hag bordering the site of the *in situ* stumps, two 0.5m metal boxes were forced into the prepared peat. Once full they were removed and the 2m of peat below was collected as four 0.5m cores, with the use of a Russian peat borer. The lowest core was incomplete and was not studied, but the coring had provided a 2.5m long sample. All of the samples were stored under refrigeration on return from the site.

One of the *in situ* stumps provided two macrofossil samples, one of which was sent for radiocarbon analysis. The other was examined microscopically in an attempt to deduce the conditions for growth from the annual growth ring pattern.

For pollen extraction and concentration 2cc samples of peat were removed from the cores at various depths. These were prepared for examination by the acetolysis method (Moore, Webb and Collinson 1991). The pollen was mounted in silicone oil and examined at x400 magnification. The pollen proved to be both sparse and poorly preserved. Counts were of 150 total pollen and spores. Identification was made with reference to Moore, Webb and Collinson (1991). Due to their similarity the pollen of Hazel and Bog Myrtle were counted together as coryloid and included amongst the arboreal pollen. The results of pollen analysis are presented as pollen diagrams, generated using the Tilia pollen diagram programme (Figures 4 and 5).

RADIOCARBON DATING

The single radiocarbon date, from the *in situ* Scots Pine stump exposed at the lochside, gave an age of 4200+/-50

radiocarbon years B.P. (before 1950 AD), expressed at the one sigma level of confidence. Using the OxCal conversion this gives an age of between 2910 and 2610 calibrated years B.C. Therefore, these Scots Pine trees were alive about 4750 years ago.

RESULTS

Peat Stratigraphy and Macrofossils

The peat recovered from the Loch Sloy site, comprised three distinct peat types, as described by the Troels-Smith method.

Stratum A 0-6 cm. Sh3Ga1, highly disintegrated and decomposed organic matter interlaced throughout with fine sand 0.06 - 0.6 mm. Few plant remains were recognisable except the roots of present surface vegetation. The junction between stratum A and B was diffuse, but discernible. The sand has probably been deposited since the reservoir was created; during that time the area has been susceptible to periodic inundation by water containing mineral material eroded from elsewhere around the Loch. The reappearance of the stumps is due to erosion of the lochside peat.

Stratum B 6-215 cm. Th^{4}4 T1+ Ag+. The surface vegetation's roots penetrated down to 150 cm, but as in stratum A most plant material was highly decomposed. There were, however, exceptions and most of the macrofossils were found here. The junction between strata B and C was easily discernible due to the nature of stratum C.

Stratum C 215-250 cm. Tb^{4}4, a darker, uniform, greasy peat of highly humified mosses. Microscopic examination found it to be composed almost entirely of mosses with some small roots and branches. Some of the mosses were still identifiable.

The macrofossils removed from the core during stratigraphic examination and from the pollen washings are listed in Table 1.

An examination of part of the root, the second part removed from the *in situ* stump, found it to contain twenty seven annual rings. The first five rings were narrow and showed little summer growth, these were followed by seven broader rings exhibiting an increase in summer growth, but the remaining fifteen rings were like the initial five, narrow and with little summer growth.

Pollen Diagrams

This can be divided into two sections; 250 to 100 cm is dominated by arboreal pollen and from 100 to 0 cm non-arboreal pollen is dominant. Closer examination allows further division into five zones which have subtler differences in their pollen ratios.

Local Pollen Assemblage Zone LS One 250-200 cm.

Table 1. Macrofossils recorded during stratigraphic examination and recovered from pollen washings.

Depth (cm)	Description of Macrofossil
7-8	Branches and stems of *Sphagnum papillosum*
18	*Calluna* twig
55-56	Burnt non arboreal fragments
60-75	Very large root, too large to remove without disrupting the core
82-83	Stems and three *Calluna* leaves, all burnt
94-95	Burnt unidentifiable fragments
100	Part of a Birch branch, *In situ* stump washed out of peat several metres from core site
104-105	*Juncus* seeds and *Eriophorum vaginatum* L. spindles
110-111	*Potentilla* seed
115-116	Burnt moss stems, *Juncus* and *Carex* fruits, bud scales of *Populus tremula* L. and fern sporangia
117-118	Bud scales, rare unidentified charcoal fragments
131-132	Burnt stems
156-157	Seeds, *Juncus* and *Potentilla*
166-167	*Juncus* seeds and large piece of *Salix* stem
175-176	Seeds and fruits of *Juncus, Carex* and *Potentilla*, mass of rotten squashed wood
182-183	Seeds of *Juncus* and fruits of *Potentilla*
190-191	Seeds and fruits of *Juncus, Potentilla* and *Carex*
195-196	Seeds *Juncus* and Birch twig
205	Small pebble
210	Unidentified wood (poorly preserved)
215	Unidentified wood (poorly preserved)
220-221	Mosses, mostly *Hylocomium splendens*, some *Polytrichum* stems and five leaves of *Sphagnum* section. *Sphagnum* (badly degraded cf. *palustre*)
250	*Hypnum cupressiforme* cf. *jutlandicum*

Zone one is dominated by arboreal pollen, the lowest value being 64% of Total Pollen and Spores (T.P.S.) at 235 cm, rising to a maximum of 75% between 227-206 cm. Although Scots Pine is present in all samples its maximum value of 4% T.P.S. at 235 cm, does not reach the 5% T.P.S. threshold required for evidence of on site presence (Fossitt, 1996; Bennett, 1996). NAP is represented by at least six angiosperm taxa and one pteridophyte. Amongst the angiosperms, Poaceae were the most important, being present throughout at between 7 and 12%. Cyperaceae were also important; although omnipresent they begin at low values rising towards the end to reach 13% at 220 cm. At 145 cm *Calluna* was present at 8% but in the rest of the zone it only reached 1%. Rosaceae were present at up to 8% and Asteraceae were present only at 235 cm, reaching 2%. Pteridophytes are represented by Filicales which reach 15% at 195 cm.

Local Pollen Assemblage LS Zone Two 220-160

Arboreal pollen begins this zone at 70% and rises to an all time high of 90% at 182 cm. This rise is short lived and by 166 cm arboreal pollen falls to its lowest value in the tree pollen dominated section at 38%. Scots Pine is scarcer than in zone one never exceeding 1% and is absent from one sample.

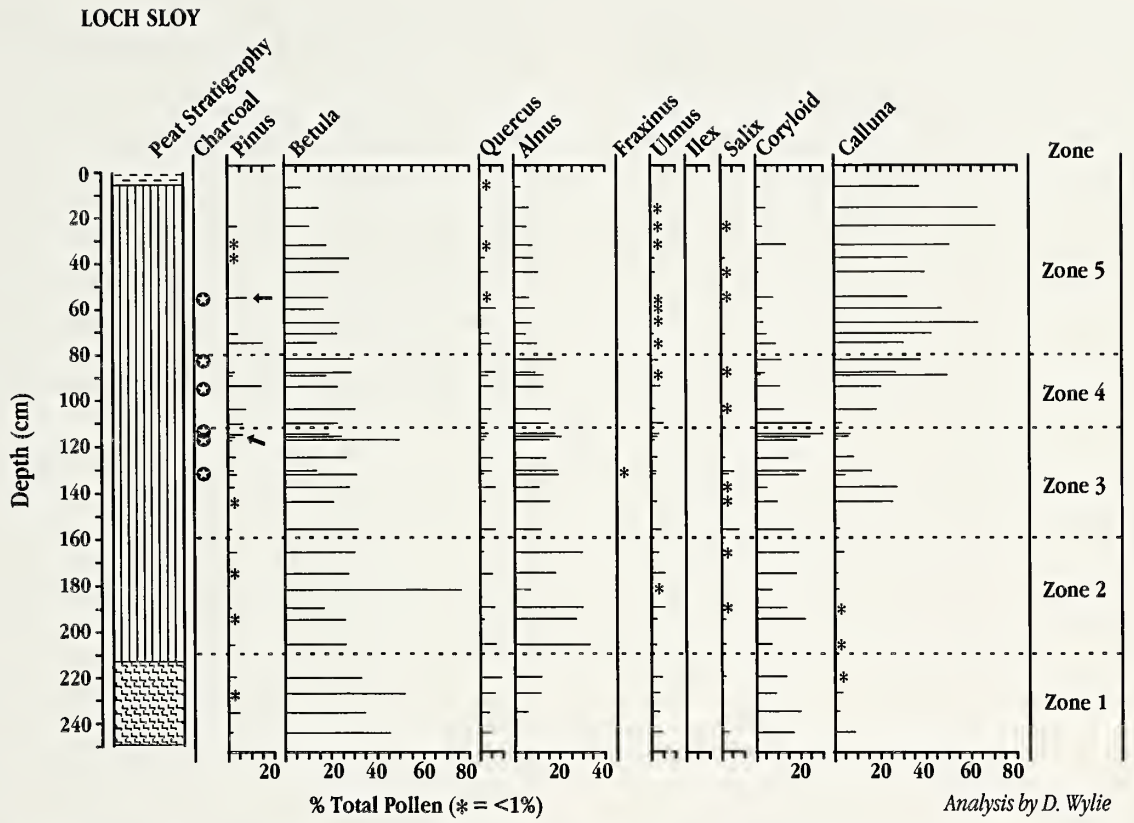

Figure 4. Pollen diagram showing the pollen of tree and tall shrub taxa which were included as arboreal pollen (AP). Also the pollen of Heaths which were included with the non-arboreal pollen (NAP). Circled stars indicate the presence of charcoal in samples removed for pollen analysis. Arrows indicate the first and last samples in which Pinus reaches 5% of total pollen.

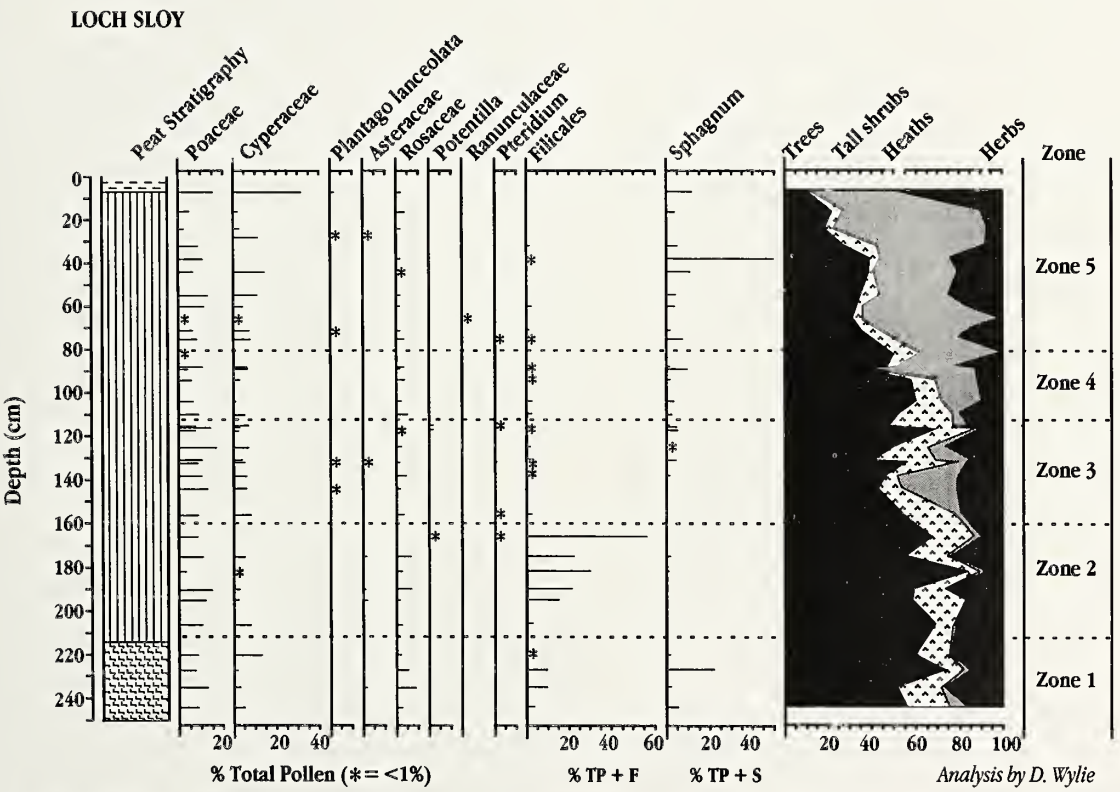

Figure 5. Pollen diagram showing the pollen and spores of non-arboreal taxa (NAP = non arboreal pollen) other than Heaths. To the right a summary diagram showing proportions of pollen of trees, tall shrubs (Coryloid = *Corylus* and/ or *Myrica*), heaths (*Calluna*) and herbs (all herbaceous plants).

NAP is low in taxa. Poaceae are well represented, Cyperaceae are present on three occasions always at below 4%, Rosaceae were in all levels and reached 7% on two occasions and *Calluna* was present also but not above 2%. *Pteridium*, Ranunculaceae and Asteraceae were all occasionally present at 1%. The most visible difference in this zone was in the pattern of Filicales spores. They rose from 15% at 195 cm to a peak of 32% at 156 cm but at 182 cm they then fell back to 23% before steeply rising to an all time high of 56% at 166 cm.

Local Pollen Assemblage Zone LS Three 160 - 112 cm

Arboreal pollen is still dominant here but there are now long periods during which this dominance is threatened by non arboreal species. At 170 cm arboreal pollen reaches its second highest value in the core, 87%. The four main tree species all undergo a series of rises and falls during this zone. Scots Pine values between 156 and 116 cm never rise above 3% but in the last level, 115 cm, Scots Pine reaches 6% breaking the 5% threshold required for evidence of on site presence. Again NAP is poor in taxa; *Plantago lanceolata*, *Pteridium aquilinum* and Asteraceae are present but only sporadically and do not exceed 1%, Rosaceae are present in all but one level with values up to 4%, Poaceae are present in all levels never falling below 7% and rising to a high of 17% at 130 cm. Cyperaceae are present in all levels, rising to 9% at 135 cm and only twice falling below 5% at 116 and 117 cm. Filicales are present in all but one sample but never rise above 5%. *Calluna* enters this zone at 3%, rises to 25% and by 148 cm it reaches 27%. It then follows a downward trend to as low as 2% at 117 cm, ending the zone on 5%.

Local Pollen Assemblage Zone LS Four 112-80 cm

This is the zone which sees the transition from arboreal to non-arboreal pollen dominance. It begins with arboreal pollen at 79%. This falls slowly at first reaching 71% at 94 cm, the last time arboreal pollen is this abundant. By 89 cm arboreal pollen has fallen to 37% but it rises again to end this zone on 62%. Scots Pine reaches threshold value in the first three levels rising to 14% at 94 cm, but in the next level it falls to 1% and at 82 cm Scots Pine is absent. Only four angiosperm taxa and one pteridophyte were recognised. From 3% at 110 cm *Calluna* rises to 48% at 89 cm but drops to 38% at 82 cm. Rosaceae falls over most of this zone from 6% at 110 cm until it is absent at 82 cm. Poaceae and Cyperaceae values fluctuate throughout this zone, the former never below 3% or above 9%, the later ranging from 1% to 8% except in level 82 cm from which it is absent. Filicales are sporadically present at between 1 and 3%.

Local Pollen Assemblage Zone LS Five 80-0 cm

At 75 cm arboreal pollen is 50%. In all subsequent levels it is below this and drops eventually to 12%; between this it falls to 36% at 60 cm and 22% at 24 cm, but recovers after each before the final decline. Scots Pine is present above threshold level in three samples; at 75 cm it reaches 14%, at 60 cm 9% and at 55 cm 8% but it drops to 3% at 71 cm and is absent at 66 cm, where it reaches 3%. Two waves of *Calluna* in this zone are separated by a trough. The waves centre on 66 and 32 cm where values are 63% and 50% respectively. The lowest value is the initial reading of 29% and the final value of 37% comes at a period of decreasing *Calluna*. Eight other families were present in the field layer. Poaceae are in most levels. They show no pattern but rise to 15% at 7 cm. Cyperaceae have a high of 31% at 7 cm, but otherwise do not rise above 14% and are absent in parts of the zone. Rosaceae are usually present but only once above 5%. Filicales were present in less than half of the levels never rising above 2%. *Plantago lanceolata*, *Pteridium*, Ranunculaceae and Asteraceae were present but at less than 2% and only in occasional samples.

The Present Pollen Rain

Table 2 shows the species composition percentage cover and percentage pollen and spores from a 10 x 10m sample quadrat taken from the site.

Pollen presently being deposited is dominated by Poaceae which comprised 67% of all the pollen and spores, more than double the sum of all other taxa combined. Other pollen types included Birch 7%, Alder 6%, *Calluna* 4%, Rosaceae 3%, Cyperaceae 2%, and Asteraceae 1%. The dominance of Birch has waned, as has the importance of Coryloid, which was absent from the surface sample, while Alder and Scots Pine have remained unchanged. The losses incurred by Birch and Coryloid have been to the benefit of Oak, which at 4% is at a level rarely attained in the last 4000 years, and three other genera which are present for the first time namely *Picea* sp. 3%. *Tilia* sp 1% and *Acer* sp 1%. These changes are easily explained by the activities of man in the last 500 years. During this time he has planted Oak and introduced *Tilia* as ornamental or amenity trees; *Acer pseudoplatanus* has also been introduced, it is grown widely in shelter belts and now regenerates freely. There has also been large scale afforestation with monocultures of alien conifers including *Picea abies* and *P. stichensis* (Norway and Sitka Spruce). At the same time as these introductions increased grazing and land improvement have lead to a reduction in natural forest. Oak woods have been less affected than others as they are often managed under coppice and standard system.

DISCUSSION

When the vegetation represented by the peat at the base of the core was alive the area around what is now Loch Sloy had a canopy dominated by Birch with some Oak, Elm and a little Alder. There was an understorey of Hazel and a field layer in which grew mosses, Poaceae, Cyperaceae, Rosaceae, *Calluna* and some Filicales. The increasing values of Alder in zones one and two are taken to represent the Holocene rise of this tree which began about 7400 years ago. If this is correct, the lowest sample examined came from peat which had begun to form well into the Holocene epoch, perhaps as much as 8000 or more years ago. Other features near the base are consistent

Table 2. Species composition, % cover and % pollen and spores recorded from a 10x10mm sample quadrat at the site.

Species/Family	% Cover	% Pollen and Spores
Molinia caerulea	40	0
Agrostis sp.	15	0
Anthoxanthum odoratum	5	0
Festuca sp.	2	0
Total Poaceae	62%	67%
Sphagnum	20	0
Polytrichum	20	0
Viola palustris	>10	0
Galium saxatile	5	0
Potentilla erecta	5	0
Total Rosaceae	5%	2%
Polygala serpylofolia	<5	0
Prunella vulgaris	<5	0
Salix aurita	<5	0
Cirsium palustris	2 seedlings	0
Leontodon autumnalis	2	0
Total Asteraceae	>2%	1%
Calluna	+	4
Pedicularis sp	+	0
Ranunculus acris	+	0
Ranunculus flammula	+	0
Total Ranunculaceae	+	0%
Carex echinata	+	0
Eriophorum angustifolium	<5	0
Total Cyperaceae	5%	3%
Juncus bulbosus	+	0
Juncus acutiflorus	2	0
Total Juncaceae	>2%	0%
Total Non-arboreal Pollen	na	67%
Betula spp.	0	7
Alnus glutinosa	0	6
Quercus sp.	0	3
Picea sp.	0	3
Pinus sylvestris	0	2
Acer pseudoplatanus	0	1
Tilia sp.	0	1
Total Tree Pollen	na	23%

with the known vegetational history of this period; Birch was the forest dominant in this area having displaced the coloniser species, such as the dwarf shrubs e.g. *Salix herbacea* (Dwarf Willow) and *Betula nana* (Dwarf Birch) as well as Poaceae and Cyperaceae, all of which flourished in late-glacial times. The predominance of Birch which is a heavy pollen producer, may be responsible for an under-representation or absence of some taxa.

Towards the end of pollen zone one the peat changes to stratum B type peat, and Alder pollen values rise at the expense of Birch and Coryloid values. On either side of the peat stratum boundary wood macrofossils are numerous proving the immediate presence of trees or shrubs.

Pollen zone two is characterised by a profusion of Filicales spores, with other important pollen types including Birch, Alder, Coryloid, Poaceae and Rosaceae. Significant macrofossils, apart from wood, included seeds and fruits particularly of *Juncus, Potentilla* and *Carex*. The quantity of *Juncus* seeds is important as the pollen of this genus is very rarely preserved. The pollen and macrofossil assemblage present indicates that at this time the site was occupied by an Alder carr.

In pollen zones three and four there are several interesting occurrences. Although still within stratum B, the amount of macroscopic wood fragments has diminished but macroscopic fossils of *Juncus, Potentilla* and *Carex* are still common. Pollen types important in zone three include Birch, Coryloid and Alder amongst the trees with some Oak and Elm. The non arboreal flora contained Poaceae, Cyperaceae and Rosaceae with *Calluna* becoming abundant for a period; some Filicales are present and *Sphagnum* begins to increase at this time. This indicates a change to peat containing minor amounts of Poaceae, Cyperaceae, *Calluna* and *Sphagnum*. Although the Alder rise is very obvious, evidence for the Elm decline is not as readily apparent. In Holocene pollen diagrams from throughout Britain there is often to be seen easily a marked drop in Elm pollen values which has been radiocarbon dated many times to about 5700-5800 years ago.

The end of zone three, which may have been about 5000 years ago, is a significant period in the history of the Loch Sloy area. Scots Pine pollen then increased to above the threshold value of 5% for the first time (see lower arrow in Figure 4) and continued to rise over much of zone four, before almost disappearing for the first time at level 89 cm. Before this time, the Scots Pine pollen present had probably been wind-dispersed from other areas. The beginning of zone four is the period during which the dated Scots Pine stump was alive. Pollen zone four sees *Calluna* rise to dominance at the expense of most other species except Oak and Rosaceae. Elm all but disappears near the end of this zone.

In pollen zone five there are no macroscopic seed remains and only one piece of unidentifiable woody material, although a few macroscopic remains of *Calluna* and *Sphagnum* are present. The pollen of *Calluna* now dominates all others, although Poaceae and Cyperaceae are still relatively abundant till about the middle of the zone. The topmost 6 cm of the core

constitute peat stratum C. Scots Pine has two peaks in this zone including a return to its maximum value of 14% and its final greater than threshold value of 7% (see upper arrow Figure 4) but it is again missing from the levels between these peaks. In the topmost six levels Scots Pine did not reach threshold values and, over what is perhaps the last 3000 years, the pollen was wind-borne to the site.

The six fires known to have occurred during the time spanned by the core are contained within pollen zones three to five, as are the high Scots Pine values. The fires began before about 5000 years ago, well within the time of Neolithic people, the first agriculturalists, and consequently may be anthropogenic. Burning appears to precede or coincide with increases in Scots Pine values and occurs simultaneously with two of the three population crashes. It seems very likely that there is some relationship between Scots Pine and burning, as suggested by Durno and McVean (1959). This may mean that fire was the agent responsible for the establishment and perhaps destruction of Scots Pine at Loch Sloy.

It is possible that the effects of the fires reduced or eliminated whatever factor or factors may have been responsible for any inhibition of the spread of Scots Pine seedlings onto the *Calluna*-dominated bog. The fires may have removed sufficient ground cover, destroyed an allelopathic agent or sufficiently dried the bog surface to allow the establishment of Scots Pine. The trees may have established at a time when the climate was becoming more oceanic; this wetness could have meant that the intervention of man was required to instigate the fires. It is suggested, however, that periods may have occurred when it was sufficiently dry to allow natural fires even at this time (McVean, 1964). Further analysis using, for example, contiguous sampling would be required to test these theories.

Rather than intermittent presence, an alternative theory is that Scots Pine may have been present on the site continuously since it first arrived during a dry period. If the climate was to deteriorate, blanket peat could have begun to spread. The wood sample taken from the Scots Pine stump showed very little summer growth even over the seven years of apparently improved growth. This indicates a tree growing under conditions of stress, possibly induced by the wetness of the bog surface. Under such conditions of high stress the tree would struggle to survive and would have produced little if any pollen. In intervening drier years pollen production could increase, as would the width of annual growth rings. This would explain the lack of Scots Pine pollen in the levels between the high values.

Elm pollen values never exceed 5% at Loch Sloy. Occurring as it did about 5400-5800 years ago the Elm decline must lie between the level of the Scots Pine stump and the base of the core. The diagram reveals three levels in which Elm values decrease, 206, 182 and 166 cm but the values return to elevated levels within the next two samples. However, the fall beginning at 144 cm does not recover over seven samples until 110 cm after which it collapses again and reaches only trace amounts for the rest of the core. The depth of 144 cm is the most likely to represent the Elm decline.

Three other cores from the Loch Lomond area have been examined in the recent past and their results can be compared to the findings from Loch Sloy. The cores are from: Ptarmigan (National Grid NN 365 015), a high altitude site 15 km south-east of Loch Sloy on the south-west subsidiary top of Ben Lomond at 500 m, with a south-easterly aspect. Shantron Muir (NS 328 878) lies 26 km to the south at 350 m with a northern aspect. Glen Falloch (NN 369 238) 12 km to the north-east at an altitude of 150 m on a south-east aspect. All were examined by Stewart (1979). Only the Glen Falloch site makes a valuable comparison.

Stewart's analysis from Glen Falloch shows remarkable parallels to Loch Sloy. The peat is not deep enough to include the Elm decline and so nothing is known of the history before 5700 years ago. At about 4850 years ago Birch was dominant and Scots Pine was present only as wind borne pollen and Alder values, unlike at Loch Sloy, were low. Dated sediment cores from Loch Lomond confirmed the spread of Scots Pine in the area about 4750 years ago. As at Loch Sloy, Scots Pine colonised *Calluna* peat, the dryness of which is attributed to favourable local conditions. Glen Falloch also shows many episodes of burning, which Stewart (1979) attributes to Neolithic man. He postulates that these events were critical in the spread of Scots Pine in Glen Falloch. A carbon-dated stump is evidence that Scots Pine grew there about 1600 years ago and it is thought that the present sparse Scots Pine trees are a disjunct population of the original native Pinewood which had been present since about 5100 years ago.

Scots Pine in the Loch Sloy area has had a complex history. If the deduced chronology is correct, then Scots Pine was present for very approximately the 2000 years between about 5000 and 3000 years ago. Any further precision in chronology can only come from radiocarbon dating of the peat. The tree arrived at the Loch Sloy site about 5000 years ago to grow on peat composed of Poaceae, Cyperaceae and *Calluna*, perhaps rendered suitable for Scots Pine colonisation by the action of fire. It invaded a community dominated by Hazel and Birch with a field layer of Poaceae, Cyperaceae and *Calluna*. Finally it vacated the Loch Sloy area about 3000 years ago. During its period of residence both the community composition and the type of peat changed. The dominance of the trees was broken, and although Poaceae and Cyperaceae usually remained at similar levels to before, they and all other taxa were swamped by the huge rise in *Calluna*. This change affected the composition of the peat which became dominated by *Calluna* with some Poaceae, Cyperaceae and *Sphagnum*.

The Scots Pine pollen levels fluctuated greatly over time; from being the dominant tree species at one point it disappears from the pollen record at others. The reason for these marked changes depends upon which theory is correct, withdrawals from the site or poor growth and flowering under stressful conditions.

Parallels with Scots Pine at Glen Falloch are striking. At both sites it invades Heather peat at about the same time and in both cases the occurrences of fire are attested by charcoal. Although Scots Pine disappeared from Loch Sloy it stubborn-

ly clings to the Glen Falloch site, presently its most southerly natural outpost. Possibly the return to more oceanic conditions prevented the recolonisation of Loch Sloy by Scots Pine due to the altitude of the site, which is 140 m higher than Glen Falloch.

The occurrence of fires has been cited by many researchers as being responsible for preparing peaty substrata for colonisation by Scots Pine and also for the destruction of the woodlands after establishment. Birks (1975) relates the action of fire to the establishment and destruction of pinewood at Cooran Lane and Coire Bog respectively, Durno and McVean (1959) relate a similar story at Beinn Eighe while Gear and Huntley (1991) report of fire before during and after a period of Scots Pine growth in Caithness and Sutherland.

That Scots Pine spread onto the slopes of Loch Sloy about 5000 years ago and vacated the area some 2000 or so years later is consistent with the main statements by Bennett (1994) as related in the introduction. The findings of coarse charcoal in samples straddling the period of maximum *Pinus* pollen strongly suggests that recurrent fires were an important factor in controlling the growth of Scots Pine on the blanket peat at Loch Sloy.

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